another. It was a sport on a staminate specimen, and on account of its striking habit was at once propagated, and has since spread over all countries of the globe. This was in the first decade of the eighteenth century, and the tree has, under all conditions of soil and climate, retained its peculiar characteristics unchanged through more than two centuries.

The story of its appearance in continental Europe is as follows: "A merchant in northern Europe received a shipment of fruit from Italy, packed in willow-twig baskets. The merchant noticed that some of the twigs had a very light gray bark. A willow of this color he had never seen before. On close examination he found that the bark was yet green and the buds very little shriveled, so he carefully unwound the baskets and made cuttings of the newly discovered willow. Some of them grew, and proved to be a new and interesting poplar."

From this small start the tree spread rapidly and soon appeared all over Europe, and finally, in less than one hundred years after its first discovery in Italy, was introduced in America.

The striking contrast with other trees and its usefulness in the variation of the sky line made it a desirable material for group and specimen plantings in parks and gardens, and soon was extensively propagated by nurserymen.

In 1872 I saw beautiful, large and healthy specimens in Pennsylvania and New Jersey. Some of them were at least forty years old, perfectly sound and uninjured by wind and cold. But trees I planted in the Topeka parks since 1900 showed unmistakable signs of decay when not more than ten years old, and in a few years more commenced to die and break off.

In examining the young trees when a year old I find that about 10 per cent have not covered the base cut with callus. The cutting turned black about an inch up and a few roots formed from the glands in the bark. By dissecting the plants I found that the decay had followed up the pith the full length of the cutting. The branches and roots were thin and the leaves smaller than those of the healthy plants. Where great care is not exercised in selecting the cuttings it will be seen that this weakness or disease will be inherited by all the descendants of the weak ancestor.

The only way to produce a healthier race of this valuable tree is by careful selection, using the healthiest wood of the healthiest trees, making both the upper and lower cut smooth, by using a sharp knife. Dip the upper cut in oil paint to exclude air and moisture, and protect the lower cut by rubbing powdered charcoal well over the surface, and if possible plant them in a sandy soil.

Problems in Artillery Ammunition Design.

R. A. Seaton.

Because of the very wide field covered by the subject as assigned to me (Scientific Engineering Problems in Ordnance Manufacture), I am limiting myself to one phase only of the subject, as indicated in the title of the paper; and the treatment of this phase is necessarily incomplete because of the limited time at my disposal and because of the complex nature of the subject. The mathematical details are eliminated in so far as possible, and an effort is made to give a more or less popular presentation of the subject in order that you may not be wearied by the more technical details.

EARLY FORMS OF AMMUNITION.

The early forms of projectiles used in cannon were solid, spherical cast-iron shot, grape and canister, the two latter being composed of a number of round shot of much smaller diameter than the bore of the gun, temporarily held together by a can, or by rods and plates, to facilitate loading. The fastenings were made so light that they would not withstand the shock of discharge from the cannon, so that the effect was very much the same as though the balls had been loaded loosely into the gun, the cannon becoming essentially a huge shotgun.

Grape and canister were ineffective except at very short ranges, and the damage done by the solid spherical shot was very small, even when a direct hit was made. An improvement was made when an explosive elongated shell loaded with black powder was introduced, but this was still very ineffective as compared with the modern high-explosive projectile.

MODERN FORMS OF AMMUNITION.

With the discovery of so-called high explosives it became possible to very greatly increase the effectiveness of projectiles against both personnel and fortifications. The modern high-explosive shell consists of a hollow steel cylinder with a conical or ogival point, filled with a high explosive sufficiently insensitive to resist the shock of discharge and capable of being detonated by a fuse fitted to the projectile. When used against matériel the shell itself acts chiefly as a carrier for the high explosive, the damage being done by the violent detonation of the explosive. When used against personnel, however, the fragments into which the shell is blown by the high explosive are projected with a high velocity and serve to materially increase the effectiveness. Early in the war it was found by experience that the effectiveness of the shell against matériel was in direct proportion to the amount of high explosive contained, so that the modern shell is made with walls as thin as will safely stand the shock of discharge, in order to carry as large an amount of explosive as possible without exceeding the permissible weight.

In chemical shells—a new development of this war—the effect is, of course, proportional to the amount of chemical which the shell carries, so that in this, also, it is necessary that the shell itself be made with as thin walls as possible.

Shrapnel, which before the war was considered to be one of the most effective forms of ammunition, proved to be relatively unimportant except against massed troops in the open—a target not often found. The shrapnel consists of a hollow steel cylinder with a pointed end, which contains a very large number of lead bullets. A pocket between the bullets and the base of the shell contains black powder, which is ignited by a time fuse while the shrapnel is still some distance from the target. This black powder blows the bullets forward and downward, spraying them over a wide area, each bullet being intended to have sufficient velocity to kill a man or horse on striking one. The shrapnel case is not blown to pieces, so that it is entirely ineffective unless it should happen to strike a living target. It can, therefore, be seen that it is desirable to make the shrapnel cases with as thin walls as possible in order that the major portion of the weight of the projectile may consist of bullets.

STRESSES IN FIRING.

The design of these shell bodies and shrapnel cases involves some rather interesting problems in the strength of materials.

With the improvement in the materials used in the manufacture of cannon, the powder pressures used have increased until at the present time pressures of 38,000 to 40,000 pounds per square inch are common. When this pressure is compared with that of about 100 to 150 pounds per square inch used in high-pressure steam boilers, or about 200 to 500 pounds per square inch in gas engines, it can be realized what enormous forces are brought to bear on the projectiles when these are being fired from the cannon. The powder pressure acts on the base of the projectile, which in turn pushes forward on the side walls. The inertia of the walls and the forward part of the shell tends to resist this pressure, so that a very heavy compressive stress is set up in the walls. This is the most obvious stress on the projectile walls, and the one which until quite recently was used as a basis for the design of projectiles. The intensity of the stress can easily be computed by the simple formula of mechanics—force equals mass times acceleration.

This is not the only important stress, however, and when it was used alone for the design of projectiles it was necessary to use a factor of safety, or, more accurately, a factor of ignorance, which sometimes gave satisfactory results and sometimes did not. The introduction of semisteel shells brought out clearly the defects of this method of design, for these shells failed at compressive stresses far below what the material could safely stand, and forced the conclusion that failure was not due primarily to these compressive stresses, but to hoop tension developed in the walls due to the pressure of the contained charge. These stresses are brought to bear in the following manner:

The high explosives which are commonly used are solids, and may be in the form of a powder pressed into the shell or may be melted and poured into it. When the shell is fired from the cannon the inertia of the charge tends to cause it to lag behind, while the particles to the rear force it ahead. This sets up a heavy internal pressure in the charge, which is greatest near the base of the shell. In shells used in the United States army this intensity of pressure frequently runs up to more than 10,000 pounds per square inch. Under such enormous pressures it is probable that the charge acts as though it were a fluid, in much the same way that the ice of glaciers acts like a fluid under heavy pressures. Consequently, the shell is in the condition of a hollow cylinder subjected to a very high internal fluid pressure, which tends to burst the walls by hoop tension. In the chemical shells the shell filler is a liquid, and it is obvious that these shells are also subjected to this hoop tension.

This tensile stress in the walls of the shells frequently runs as high as, or higher than, the compressive stresses in the walls due to direct powder pressure. As the tensile strength of semisteel is only from one-third or one-fourth of the compressive strength, it can readily be seen why the attempt to design semisteel shells on the basis of compressive stresses gave unsatisfactory results. The effect of the longitudinal compression and the hoop tension acting simultaneously is much more severe than it would be for either of these acting singly, and it is commonly the combined effect of these stresses which limits the ability of either steel or semisteel shells to with-

stand discharge from the gun. A number of other stresses also exist, such as those due to centrifugal force and to the rapid angular acceleration of the shell, but these may usually be neglected without serious error.

HIGH QUALITY OF STEEL REQUIRED.

The combined stresses in shells used in our service frequently run as high as 60,000 pounds per square inch, which makes necessary the use of a high quality of steel in their manufacture. Ordinary steels are not able to withstand these stresses, and if used without special treatment would allow the shell to swell in the bore of the gun. This would be very likely to cause a premature detonation of the charge, with the destruction of the gun and its crew. On the other hand, high carbon steels of the quality which could safely withstand these stresses would be so hard as to make it difficult and expensive to manufacture them. It is therefore necessary to make use of an intermediate quality of steel and by the use of appropriate heat treatment after the shell is manufactured to give it the desired strength. When semisteel is used for shell manufacture a radically different design must be used, with much lower tensile stresses. This considerably reduces the amount of charge which can be carried and renders the shell inefficient.

The very high stresses developed, and the seriousness of a possible failure of the shell to stand up properly under firing, make necessary very careful inspection and testing of the shells during and after manufacture. The final test as to the acceptability of the shell is, of course, the firing test, and this is made upon a considerable percentage of all shells manufactured, a nonexplosive charge of the same specific gravity as the high explosive being used. In order to give a margin for safety, a powder pressure about 12 per cent in excess of the normal is used. The shells are recovered after firing, and inspected to observe whether any appreciable swelling has taken place. If this has occurred the entire lot from which the samples were taken must be rejected.

INCREASED RANGES USED.

One of the important developments of this war has been the increase of range obtained with the artillery. The importance of being able to outrange the enemy is obvious. It was largely because the French 75 mm. guns outranged the German guns of a similar caliber that the French were able to stop the Germans in the early part of the war in spite of great disadvantages in other respects. The Germans recognized this, and greatly improved the ranges of their various calibers of guns during the progress of the war.

An increase in range can be secured in one of three different ways, or by a combination of these, namely, (*a*) by increasing the powder pressure; (*b*) by increasing the length of the gun, so that the powder pressure can act on the projectile for a longer time; or (*c*) by improving the shape of the projectile.

Either of the first two methods will result in giving the projectile an increased muzzle velocity, while the third method will result in decreasing the resistance of the air to the flight of the projectile.

Disadvantages attending the increase of powder pressures are that the stresses in both gun and projectile are increased, erosion of the gun is increased, and its life is shortened. The gun must be made heavier to stand the increased stresses, and it consequently becomes less mobile.

Increasing the length of the gun also increases the weight and makes the gun less mobile. It is therefore highly desirable that the improvement in the shape of the projectile should be carried as far as practicable.

EFFECT OF SHAPE OF PROJECTILE ON RANGE.

In a vacuum the path or trajectory of a projectile would be a parabola, and the projectile would have the same velocity at the target that it had at the muzzle of the gun, assuming these to be in the same horizontal plane. The maximum range would be obtained with an angle of elevation of 45 degrees and the range obtained for any given angle of elevation would be directly proportional to the square of the muzzle velocity. It may be noted in passing that in a vacuum the axis of the projectile would not remain tangent to the projectile's path, but would remain always parallel to its original direction.

At the high velocities used with guns the resistance of the air to the motion of the projectile becomes very important. With certain artillery projectiles used in our service the air resistance at service velocities is a force equal to from ten to fifteen times the weight of the projectile. Due to this resistance, the range is greatly decreased, the path is no longer a parabola, and the range is no longer proportional to the square of the muzzle velocity.

It is readily seen that the ability of the projectile to penetrate a resisting medium such as the air will depend on the pointedness of the projectile, and that the more pointed the projectile the greater the range that can be obtained with a given muzzle velocity. It can also be seen that for a given resistance of the air the retardation will be inversely proportional to the weight of the projectile. It follows, therefore, that increasing the length of the projectile of a given size will increase the range, since this will increase the weight without greatly affecting the air resistance. This is one of the great advantages of the cylindrical-ogival form of shell over the spherical one. But there is a limit beyond which the increase of length must not be carried. When the latter becomes greater than about four times the diameter, the projectile becomes unstable and will no longer move point forward, but will tumble and thus present a very greatly increased area to the resisting air, and the range will be short and very erratic. The length of projectile which will be stable may be increased somewhat by the use of a light, hollow cap, which will throw the center of pressure forward without greatly disturbing the position of the center of gravity.

Another method used to decrease the resistance of the air is to slightly taper the rear end of the projectile, very much in the same way that the rear portion of the boat is tapered. It is because of this similarity that this tapering is given the name of boat-tailing. Boat-tailing has been very generally used on projectiles designed in the last few years.

OTHER FACTORS AFFECTING RANGE.

Another very important factor which affects the range of projectiles is the air density. The retardation is directly proportional to the density of the air, and consequently an increase or decrease of one inch in the barometer will change the retardation by about one-thirtieth of its value. It is an interesting fact not usually understood that a moderate change in the barometer will change the range of a projectile more than a strong head wind.

The modern long ranges are obtained by firing at high angles of elevation,

the maximum range being obtained at an angle of from 40 to 50 degrees. The projectile, therefore, rises to a considerable height above the earth, and the air density at this altitude is much less than that at the surface of the earth, thus materially decreasing the retardation of the projectile.

POSSIBILITIES OF VERY LONG RANGES.

The firing of shells upon Paris by the Germans from a distance of about 75 miles has drawn attention to the possibility of securing very long ranges.

It happened that I was in the ordnance department at Washington at the time the Germans began firing these projectiles, and the War Department called upon me to calculate the elements of the trajectory and determine whether it were possible that the Germans were really firing on Paris from such a distance as was reported.

Ballistic calculations are usually made by the aid of tables, in very much the same way that tables of the functions of the angles are used in the solution of problems in trigonometry. A brief preliminary investigation showed that while the tables extended only to a velocity of 3,600 feet per second, this velocity would be much too low to give the necessary range. It was therefore necessary to resort to an analytical solution based on graphical analysis, and to solve the trajectory step by step. The process was a tedious one, but the calculations gave the desired results. It was found that for the assumed data regarding the projectile, and an angle of elevation of 50 degrees, a muzzle velocity of about 5,000 feet per second was required; that the projectile would rise to a height of about 25 miles above the surface of the earth; that the time of flight would be about 3 minutes; the angle of fall about 56 degrees, and the striking velocity about 2,800 feet per second. These results check satisfactorily with the latest information available.

It should be noted that in making these calculations it was necessary to extend both the laws of variation of air resistance with velocity, and of air density with altitude, far beyond the limits of experimental data. Very little experimental work has been done with velocities greater than 3,000 feet per second, while 25 miles above the earth's surface is several times as high as has ever been reached by man.

It is interesting to compare these results with the values required to give a 75-mile range *in vacuo* with an angle of elevation of 50 degrees. Very simple calculations show, for the latter case, that the muzzle velocity required is about 3,600 feet per second, the maximum height above the earth's surface about 22 miles, and the time of flight about 171 seconds. The only one of these values differing greatly from the corresponding one for flight in air is the muzzle velocity. The reason for this is that the major portion of the actual trajectory was in what is practically a vacuum. About four-fifths of the range was covered at a height of over nine miles above the earth's surface, and hence in an air density less than one-seventh that at the earth's surface, while the density at the highest point of the trajectory is about $\frac{1}{200}$ that at the earth's surface. The great decrease in velocity of the projectile comes in the first few miles of its travel, while it is going through the dense atmosphere near the earth.

There is no question but that had the war continued there would have been a further development in the matter of very long ranges. How far the increase in range would have gone is problematical.

It may be interesting to note in this connection that calculations show that, neglecting the retardation of the air, it would require a muzzle velocity of only about seven miles per second to make a projectile leave the earth entirely and never return, while with a velocity of about five miles per second, only five times that reached in the German gun, the projectile would revolve around the earth as a satellite. Obviously, velocities somewhat short of these values would be sufficient to reach from any one point of the earth's surface to any other point, if the resistance of the air could be neglected. To actually accomplish the result it would be necessary only to give a sufficient added velocity to the projectile so that it might have the velocity mentioned by the time it had risen above the earth's atmosphere. Whether it will ever be possible to design a gun capable of giving such a velocity to a projectile is a problem for the future.

Factors Influencing the Teaching of Science and Engineering.

A. A. Potter.

The following factors contribute to efficient instruction:

1. Organization. The duties of every person connected with the administration, instruction and research activities of an educational institution should be carefully worked out, showing lines of authority and of responsibility. A diagram should then be drawn up which shows at a glance to whom each individual in the organization is responsible, and the main duties, whether executive, teaching or investigational, every person is performing. This chart should be supplemented by departmental charts and by written instructions, which should set forth details of organization.

It should be the duty of the head of the institution to familiarize the heads of the various departments with the organization. The heads of departments should be held responsible for the quality of instruction in their departments.

To correlate the work of the various instructors in any given department, frequent conferences should be held of all instructors teaching the same or related subjects. These conferences should be very informal and should aid in developing *esprit de corps* among the instructors, while improving teaching methods and bringing out defects in textbooks, schedules of assignments, subject matter, etc.

The head of the institution should also hold frequent conferences of all department heads in order to correlate the work of the various departments and to discuss administrative details. Matters affecting the entire teaching force should be discussed at general meetings, which should be attended by every person connected with the institution.

When several instructors are teaching the same subject, but to different sections, the schedule of instruction should be planned by a committee including all such instructors, and in coöperation with the head of the department. If at all possible, where several instructors are handling the same subject, the sections should be arranged so that men possessing similar qualifications are assigned to the same section. Greatest aid—that is, better teachers and smaller sections—should be set aside for those students of lesser ability who show a desire to make most of their opportunity.